KEK Site for JLC

A preliminary Study

(We also work on some mountain sites.)

T. Matsuda/K. Fujii
With helps of many people.

KEK/IPNS

@ ISG8

25 June, 2002
KEK Site: Motivations

JLC Site Study Group

Two different Categories of JLC Candidate Sites:

(A) The regions that (are supposed to) provide a stable bedrock
   \[\rightarrow\] about 10 candidate regions.

(B) The regions where the Japanese government promotes Science and Engineering
   \[\rightarrow\] KEK site (soil)
   Some more (bedrock or soil)
Categories (A) Sites

Base: Bedrock

① Ground vibration → Mostly in the mountain areas where human activities are minimum. No ground vibrations beside those of natural origins (mountain stream etc) and the LC itself although no measurement has done yet at any of the candidate sites. The slow motion?

② Civil engineering → NATM+TBM provides a flexible and well-established technology. The construction cost is well understood (even in Japan).

③ No technical issue of building a huge experimental hall. The size of the hall is just a matter of cost.

④ Need a detailed geological survey to fully understand the quality of deep rock (faults, underground water etc.), or possible extra tunneling cost.

⑤ Require a new laboratory of ￥70B (the site development & buildings of the present KEK size) + basic equipment +human resource.

⑥ Somewhat less favored research and living environment for the international laboratory.
KEK Site

Base: Clay, Sand & Gravel.

① The ground vibration of human activities (traffic, the activities at KEK etc. though no real industries) and the issue of the stability O (< 1 mm) of tunnels. The vibration measurement planned in JFY2002.

② Tunnel engineering → No technical problem of the shield tunnel construction. The cost of the shield tunnel has not been stabilized (= optimized) yet in Japan. The unit cost/m should be TBM cost + shield segment cost (30 –50%).

③ The change of ground conditions and the existing of the underground water rarely obstruct the construction of shield tunnel itself.

④ The construction of a deep underground experimental hall in the soil with underground water is a technical and cost issue.

⑤ Possible to fully utilize the human and material resources at KEK.

⑥ The best research and living environments.
A Cost Estimate of “A New Laboratory”
(The Size of Present KEK) @LC02
(Site, Buildings Only)

200 ha
500 staff members  74.5 BY (+ Equipment)
500 visitors

(100 MY )

I. Campus

Site Development  200 ha  128
( With Road, Water Supply, Sewage, Drain etc)

Buildings:

- Office (Research)  25,000 m²  100
- Office (Administration)  4,000 m²  16

- Experimental  12,000 m²  60

New lab  KEK

545

35,000 m² (*)
(*) Not incl. the experimental halls used by on-going experiments.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Area (m²)</th>
<th>No.</th>
<th>Total Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computing</td>
<td>2,000</td>
<td>10</td>
<td>4,000</td>
</tr>
<tr>
<td>Radiation Safety</td>
<td>2,000</td>
<td>10</td>
<td>4000</td>
</tr>
<tr>
<td>(Incl. Chemistry Lab.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cryogenic &amp; Vacuum</td>
<td>2,000</td>
<td>10</td>
<td>3000</td>
</tr>
<tr>
<td>Machine Shop</td>
<td>2,000 m²</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Utility Buildings</td>
<td>2,000</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Other Utilities</td>
<td>2,000</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Dormitory &amp; Guest House</td>
<td>7,500</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Parking, Sport Facilities, Tree-planting, Reserved Area etc</td>
<td></td>
<td></td>
<td>135</td>
</tr>
</tbody>
</table>

II. **Housing for staff members:** 50,000 m² 200

III. **Equipments:** A fraction of 1600 (**)

(**) All Equipments > @5k $ listed At KEK in March 2000
Tsukuba Area & KEK
(Plan A)
Tsukuba Plateau (20-30m SL)
Geology of Tsukuba Plateau

Bedrock starts at $-621\text{m}$ at this location.
At KEk at around $-400\text{m}$.
Enviomental Geologic Map of Tsukuba City

A–G: Cross sections (East–West)
G–K: Cross sections (North–South)
Tsukuba
Geologic Sections
East-West
(A−F)
(30m ~ −40 mSL)
Tsukuba
Geologic Sections
North–South
G–K
(30m ~ -40 mSL)
Geologic Cross sections
(30m ~ 70m SL)
(Three borings at KEK)
Comparison with the KEK boring

図-11  JLCルートに沿ったKEK付近のポーリング柱状図と地質断面図

Sakura River

SAKURAGAWA TEICHI

KEK
KEK Site: Plans

(necessary path of the JLC site study)

Leaving the most important issue behind,

Examine the remaining issues.

**Plan A: 22 km**

Main linac: 8.3 km x 2 + Injection energy x 2.

(Final focus: 2 km x 2)

**Plan B: 10 km**

A contingency plan for only 400-500 GeV
Using only the central part of the plan A.

Only 30% of the tunnel in length passes under Personally owned land.

May be expanded in the second stage.

Main linac: 3.8 km + Injection energy x 2.

(Final focus: 0.7 km x 2)
KEK Site: Plan A (22km)

Minimize the tunnels to pass under the personally-owned land:

→ The tunnels go under a main road of Tsukuba City. Probably the most disfavored place from the point of the ground motion.

→ Under a research park and a small river etc.

Minimize the surface facility:

→ Centralized injection system at the present KEK site and a nearby reserve.

Shield Tunnel Technology:

→ Build the damping rings at the surface level (-10 m ~ -30 m) in KEK.

Standard rule of the compensation for loss of land price due to underground construction:
Interference to/from activities on the surface:
Possible dumping of the ground vibration (to be measured):
The stratum favored for the tunnel stability (to be studied):

→ The tunnel depth > 40m, possibly 80m.
Fig. 2

**Injector and Pre-accelerator Section**
- Open Cut Tunnels (-10m deep)
- Klystron Gallery on Top
- Silent Tunnels (10% slope)
- Accelerator Tunnels and Detector Hall (-60m deep)
- Klystron Gallery (-74m deep)

Collimator Section with IF Collimation
107 m for E= 200 GeV/
267 m for E= 500 GeV/
Pre-accelerator Lines (-17m) have sparsely spaced accelerating structures to share Klystron galleries with Main Lines.

**JLC @ KEK site**
**Plan view**
(Plan A: 22 km)
KEK Site: Plan A (22 km)

Tunnel Layout

- Injector system up to the damping rings is on the surface (-10 m).
- Inclined (10 %) tunnels to transport 1.98 GeV electron and positron to the main linac tunnel (~ -80 m).
- Main linac tunnel (3 m φ) with an arc at each end at ~ -80 m.
- The cross section of the main linac tunnel is “locally expanded” (3 m φ → 4.5 m φ) to accommodate the first bunch compressors and the pre-linacs are installed in the main linac tunnel.
- The main linac tunnel (of the standard cross section of 3 m φ) also accommodates the transport lines, the second bunch compressors.
- The klystron tunnel (4.5 m φ) and the main linac tunnel, which is separated by 5 m, are located diagonally so that one shaft can serve for the two tunnels in the drilling and the operation.
- In some case, the underground conjunction of two tunnels is made without shaft improving the stiffness of the soil by the freezing technique or the injection (hardening agent) method.
JLC @ KEK Site (Plan A: 22km)
Tunnel Layout
JLC @ KEK site
Tunnel Layout

Each shaft serves for the two tunnels.
Shaft: 15 - 20 m φ

Klystron & Linac tunnel

Krystron & Linac tunnel
Cost of the Shield Tunnel in Japan
Expensive: Why?

A Comparison between Germany and Japan
For a specific example: 1997
(By “Nikkei Construction”)

For a specific Tunnel
Two tunnels parallel vertically.
Length of the tunnel: 3.6 km x2.
Segment Diameter: 15 m. (t = 60 mm)
Depth: 15 m and 35 m.
Non solidified silt
Shaft
35 m φ, thickness of the wall: 3.0m
Thickness of the Diaphragm Wall: 2.0m.

Cost Ratio: Japan/Germany

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (Direct cost)</td>
<td>2.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>(Incl indirect cost)</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Shaft</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Segment</td>
<td>4.5(*)</td>
<td>2.0</td>
</tr>
</tbody>
</table>

(*) In the case of 5m class tunnel: ~2)

While:

Material/labor Cost Ratio: Japan/Germany

<table>
<thead>
<tr>
<th>Material</th>
<th>Japan/Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steal</td>
<td>0.5-0.36</td>
</tr>
<tr>
<td>Freshly mixed concrete</td>
<td>1.2</td>
</tr>
<tr>
<td>Cement</td>
<td>0.8</td>
</tr>
<tr>
<td>Labor</td>
<td>0.6</td>
</tr>
</tbody>
</table>
# Cost of Shield Tunnel

## Break Down

<table>
<thead>
<tr>
<th>Items</th>
<th>JAPAN (%)</th>
<th>Germany (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft:</td>
<td>6.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Segment:</td>
<td>45.2</td>
<td>23.3</td>
</tr>
<tr>
<td>Filling(*):</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Digging:</td>
<td>7.6</td>
<td>15.1</td>
</tr>
<tr>
<td>Shield machine</td>
<td>13</td>
<td>25.8</td>
</tr>
<tr>
<td>Mud Transport</td>
<td>3</td>
<td>5.7</td>
</tr>
<tr>
<td>Others</td>
<td>11.8</td>
<td>11.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

(*) between the ground and the segment.
KEK Site: Plan A (22 km)

Cost of the Civil Engineering Only

Very Preliminary and unofficial
Note: Not including the indirect cost (~ 30 %)

An Estimate with a Exp. Hall (Case 1)

<table>
<thead>
<tr>
<th>Items</th>
<th>(¥100M)</th>
<th>(¥k/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injector: (open cut)</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Tunnels: (Shield)</td>
<td>542</td>
<td></td>
</tr>
<tr>
<td>(Incl. the inclined tunnels)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 m φ  x 22.2 km</td>
<td>(202)</td>
<td>900</td>
</tr>
<tr>
<td>4.5m φ  x 25.1 km</td>
<td>(340)</td>
<td>1350</td>
</tr>
<tr>
<td>Shafts for the shield machines:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 m φ , 85 m deep x 4</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>Tunnel connections (x 2)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Connection holes:</td>
<td>----</td>
<td></td>
</tr>
<tr>
<td>Floor for the 4.5m φ tunnel</td>
<td>----</td>
<td></td>
</tr>
<tr>
<td>Experimental hall (Case 1)</td>
<td>56.3</td>
<td></td>
</tr>
<tr>
<td>(NATM after improving the stiffness of the ground)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>~ 32 m φ x 60 m long</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>717</td>
<td>(without the indirect cost)</td>
</tr>
</tbody>
</table>
Experimental Hall: Case 1 (30m φ x 60m L)  
by The City NATM

実験室(案) S=1:1,000

Shaft

縦断図  断面図
Experimental Hall: Case 1 (30mΦx60mL) by The City NATM

支保工(ロックボルト, 吹付コンクリート)
KEK Site: Plan A (22 km)

Cost of the Civil Engineering Only

Preliminary and unofficial
Including the indirect cost 38%

An Estimateion with an Small Experimental Hall
By the Diaphragm Wall method.
(Only 1/3 of Case 2)

<table>
<thead>
<tr>
<th>Item</th>
<th>(¥100M)</th>
<th>(¥k/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injector (open cut)</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Tunnels (shied)</td>
<td>662</td>
<td></td>
</tr>
<tr>
<td>(Incl. the inclined tunnels)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 m φ x 22.5 km</td>
<td>(263)</td>
<td>1170</td>
</tr>
<tr>
<td>4.5m φ x 24.2 km</td>
<td>(399)</td>
<td>1650</td>
</tr>
<tr>
<td>Shafts for the shield machines:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15m φ , 75 m deep x 6*</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Access shafts:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3m φ ,70 m deep, x 4</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Connection holes for RF :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30cm φ , total 9.7 km</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Floor (4.5 m φ tunnel only)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Experimental hole:</td>
<td>152</td>
<td></td>
</tr>
<tr>
<td>50 m φ (Diaphragm wall method)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>987</td>
<td></td>
</tr>
</tbody>
</table>

(include the 38% indirect cost)
Experimental Hall (30m x 30m x 100mL)
by Three Diaphragm Walls
(Case 2)
KEK Site: Summary

If the criteria for the ground motions
Might be proven to be met at the KEK site
By the planned measuring the ground motion
(Planned in JFY2002)
Or
By a faster and non-expensive feed back systems,

Then
The KEK site will become
One of the attractive sites for (J)L.C.

Some other issues:

- The construction method and cost of the experimental hole
  → An challenge for the civil engineering companies.
- Reduction of the cost of the shield tunnel in Japan
  → An effort to destroy the notorious “Kanryou Kisei”.
- Acceleration field gradient high enough to satisfy the world
  HEP community
  → An real challenge for the accelerator physicists.
- Agreement by the local community
  → A good task for the management of institute.
- · · · · · · · · · ·